METHOD AND DEVICE FOR PROCESSING VIDEO DATA BY USING SPECIFIC BORDER CODING

The present invention relates to a method for processing video data to be displayed on a display screen by providing said video data having video levels selected from a predetermined number of video levels, encoding said predetermined number of video levels with a corresponding number of codewords and illuminating pixels in a central area of said display screen in accordance with said codewords.

Furthermore, the present invention relates to a corresponding device for processing video data.

Background

Referring to the last generation of CRT displays, a lot of work has been done to improve its picture quality. Consequently, a new technology like Plasma has to provide a picture quality at least as good or even better than standard CRT technology. For a TV consumer, high contrast is one main factor for a high subjective picture quality of a given display. The dark room contrast is defined as the ratio between the maximal luminance of the screen (peak-white) and the black level. Today, on plasma display panels (PDP), contrast values are inferior to those achieved for CRTs.

This limitation depends on two factors:

- The brightness of the screen is limited by the panel efficacy that in general is lower than that of a CRT for a given power consumption. Nevertheless, the PDP efficacy has been constantly improved during the last years for the benefit of contrast.

- The black level of the PDP screen is not completely dark like on a CRT. In fact, a backlight is emitted even while displaying no video signal. The plasma technology requires for the successful writing of a cell a kind of pre-excitation in the form of a regularly priming signal representing an overall pre-lighting of all plasma cells. This priming operation is responsible for the backlight, which drastically reduces the PDP contrast ratio. This reduction is mostly visible in a dark room environment representing the major situation for video applications (home theatre etc.)

In the following, aspects of response fidelity and priming are presented in more detail.

A panel having good response fidelity ensures that only one pixel could be ON in the middle of a black screen and in addition, this panel has a good homogeneity. Figure 1 illustrates a white page displayed on PDP having response fidelity problems. The response fidelity problems appear in the form of misfiring of cells having too much inertia. Such cells require more time for writing as available.

A first solution to achieve good response fidelity, by standard PDPs and for a given addressing speed, leads to the priming operation mentioned above. In that case, each cell will be repeatingly excited. Nevertheless, since an excitation of a cell is characterized by an emission of light, this has to be done parsimoniously to avoid a strong reduction of the dark room contrast (i.e. to avoid more background luminance). Therefore a simple way to improve the dark room contrast leads to an optimization of the priming use.

Actually, two kinds of priming can be found on the market:

- "Hard-priming" which generates more backlight (e.g. 0,8 cd/m^2) but which has a very high efficacy. Usually, one single "hard priming" per video frame is sufficient.

- "Soft-priming" which generates less backlight (e.g. 0,1 cd/m^2) than the previous one but has less efficacy. On many products, this priming is used for each sub-field, which leads to a very poor dark room contrast again.

Obviously, the better solution should be based on the use of a "soft-priming" with the assumption that the total amount of "soft-priming" required to obtain an acceptable response fidelity will produce less light than a single "hard-priming". This is not the case when the coding has not been optimized since one priming per sub-field should be required.

In fact, the best contrast ratio will be obtained by using a single soft-priming operation per frame. Such a concept is achieved by optimization of the coding concept as seen in the next paragraph.

The document EP-A-1 250 696 introduces a concept of one single "soft-priming", where only one priming at the beginning of a frame is performed. In that case, only the first sub-fields will be near enough from the priming signal in the time domain to benefit from it. Now, the main idea was to use these first sub-fields as a kind of "artificial priming" for the next sub-fields taking the assumption that one lighted sub-field will help the writing of the next ones (cascade effect). Figure 2 illustrates this "cascade effect" in the case of a 12 sub-fields code by analyzing the jitter of the writing discharge for the last sub-field (most significant bit MSB). It represents the statistic distribution of the writing discharge of the last sub-field inside the plasma cell for two different codewords by respective enve-

lope curves. In both situations, there is only one priming (P) at the beginning of the frame (not shown).

In the first case, the codeword used (P-101111111101) enables a good cascade effect from the priming P up to the last sub-field (MSB). Then, the distribution of the writing discharge is well concentrated and fully occur inside 1,1 µs which represents the new borderline for the address speed. This means, that the writing process can be performed within the addressing period.

In the second case, the codeword used (P-000000000001) does not permit any cascade effect and therefore the writing of the last sub-field is less efficient. Then, the distribution of the writing discharge is no more concentrated and is spread on a longer time period as shown by the envelope. Thus some writing process would be performed after the addressing period. In that case, more time should be given to the addressing for acceptable response fidelity.

The results presented in Figure 2 have shown that good response fidelity can be obtained through a kind of cascade effect from the priming up to the highest sub-field. In that case the initialization started with the priming will spread like a wild fire among the whole frame. Therefore, an optimized concept will require a concentration of energy around the low sub-fields, which are the most critical ones to ensure them a maximal benefit from the priming. In addition to that, the time delay between two consecutives lighted subfields should be kept as small as possible to increase the influence between them and to produce an optimal cascade effect starting with the priming.

Figure 3 illustrates various ways to encode the video level 33 with two different sub-field organizations. Depending on the sub-fields organization, there are one or more encoding possibilities for a video value. A binary code shown on the

left side of Figure 3 leads to a large space between two sub-fields ON. Therefore, there is no influence between these sub-fields and no concentration of energy in the low sub-fields. As a result, more priming or longer addressing time is needed. A redundant code presented on the right side of Figure 3 enables a better concentration of the energy around the priming and also enables to reduce the distance between two sub-fields ON so that the cascade effect can be utilized.

Moreover, the optimal sub-fields encoding should enable to have not more than one sub-field OFF between two sub-fields ON. This property will be called Single-O-Level (SOL). An optimized sub-field weighting based on the mathematical Fibonacci sequence enables to fully respect the SOL criterion.

Figure 4 illustrates an example of coding used for all further explanations (11 sub-field redundant coding). The frame depicted here starts with a priming operation. After that, a sequence of sub-fields follows. Each sub-field starts with an addressing block. According to the value of the sub-field a time period for applying sustain impulses follows. At the end of each sub-field a plasma cell is reset by an erasing operation.

Nevertheless, some experiments have shown that, under some circumstances, even a SOL criterion combined with a single "soft-priming" is not enough to provide perfect response fidelity.

In the following the specific problem of the present invention is demonstrated. Experiments have shown that, when the number of sustains grows, the biggest sub-fields will suffer from response fidelity problems. These problems appear only under certain circumstances, for instance in the case of a horizontal greyscale at a high sustains number as shown in Figure 5. When the number of sustains is increased, some re-

sponse fidelity problems appear at the PDP borders. However, this does not appear in a homogeneous way but only some specific video levels are disturbed.

Invention

In view of that it is the object of the present invention to provide a method and device for processing video data, which remove the PDP border problem.

According to the present invention this object is solved by a method for processing video data to be displayed on a display screen by providing said video data having video levels selected from a predetermined number of video levels, encoding said predetermined number of video levels with a corresponding number of codewords and illuminating pixels in a central area of said display screen in accordance with said codewords, as well as illuminating pixels in a border area surrounding said central area of said display screen by using only those codewords of said number of codewords, which have a constant bit value in a selectable part of the codewords.

Furthermore, according to the present invention there is provided a device for processing video data to be displayed on a display screen including data providing means for providing said video data having video levels selected from a predetermined number of video levels, encoding means for encoding said predetermined number of video levels with a corresponding number of codewords and illuminating means for illuminating pixels in a central area of said display screen in accordance with said codewords, wherein said illuminating means is adapted for illuminating pixels in a border area surrounding said central area of said display screen by using only those codewords of said number of codewords, which have a constant bit value in a selectable part of the codewords.

Preferably, codewords, which have a binary 0 between two binary 1, are not used for illuminating the border area. Thus, cells of the display screen being ON cannot pollute surrounding cells being OFF.

Video levels corresponding to codewords being not used may be recreated by dithering. With such dithering every video level can be created by temporarily switching on an off a higher video level.

In a preferred embodiment a part of the codewords having constant bit value may be determined by a power level of a picture to be displayed. Since the pollution of neighbour cells depends on the power level of a picture, it is advantageous to adapt the coding of the video levels to the power level.

Moreover, the part of the codewords being determined to have constant bit value should include the most significant bits of the codewords. Thus, especially those codewords are not used for coding video levels, the high level sub-fields of which are on and off alternatingly. Consequently, cells of the display screen being energized by a lot of sustain impulses according to high level sub-fields will not pollute neighbouring cells being OFF.

The border problem is reduced towards the centre of the display screen. Therefore, the border area is preferably divided into several sub-areas, wherein the non-usage of codewords is stepwise reduced. A first one of said several sub-areas may be illuminated by codewords with a first selectable part of constant bit value and a second one of the several sub-areas may be illuminated by codewords with a second selectable part of constant bit value, wherein the second selectable part includes the first selectable part of codewords or at least a portion of it or is different from the

first selectable part. In a preferred embodiment the length of the part within a codeword in which the bit value is constant, is variable starting from the most significant bit of a codeword.

Drawings

Exemplary embodiments of the invention are illustrated in the drawings and are explained in more detail in the following description. The drawings showing in:

Fig. 1 a dual-scan PDP having response fidelity problems;

Fig. 2 a cascade effect for last sub-field writing;

Fig. 3 various coding possibilities towards a single-0-concept;

Fig. 4 an example of the single soft-priming concept;

Fig. 5 a typical PDP border problem;

Fig. 6 the structure of a PDP before sealing;

Fig. 7 the structure of a PDP after sealing;

Fig. 8 a zoomed part of Figure 5 having the border problem;

Fig. 9 a codeword comparison of the codewords of Figure 8;

Fig. 10 a zoomed part of Figure 5 having no border problems;

Fig. 11 a codeword comparison of codewords of Figure 10;

Fig. 12 an ON/OFF pattern in case of closed cells of a display screen;

Fig 13. an ON/OFF pattern in case of open cells of a display screen;

Fig. 14 a general concept of a power management;

Fig. 15 a function showing the linkage between the power consumption and the number of sustains per frame for a power management applied to a PDP;

Fig. 16 an evolution of sustain sequence versus the average power level;

Fig. 17 critical sub-field for response fidelity;

Fig. 18 display screens with different border areas; and

Fig. 19 a block diagram of a hardware implementation of a device according to the present invention.

Exemplary embodiments

The present invention is based on the knowledge that the structure of a PDP in its centre is different from that in the border area. In detail plasma panels are built with two glass plates (front and back) sealed together and having electrodes on top of them (horizontal transparent electrodes on the front plate, vertical metallic electrodes on the back plate). The various plasma cells (Red, Green and Blue dots) are delimited through so-called barrier-ribs having a certain height. This height also normally defines the distance between the two plates. This basic concept is illustrated in Figure 6 for a PDP sealing. There is a height difference between the ribs and the seal being arranged at the border of the plasma panel. Indeed, in order to have a perfect seal-

ing, it is needed that the seal is higher than the ribs. On the other side, the precision in this height is not very fine today and will also depend on the sealing process. Indeed, during that process, the seal will be molten. The result of the sealing process is shown in Figure 7. In the middle of the screen (far from the seal) the cells are completely closed, whereas, at the border of the screen, near the seal, the cells are open.

This geometrical situation will have a strong impact on the panel response fidelity, above all for very energetic pictures (pictures with a lot of sustains).

In the introductory part the concept enabling the use of only one single priming operation in the case of an optimized encoding has been presented. This concept of single priming works very well in case of full-white pictures having a limited maximal white value (e.g. 100 cd./m^2 with around 150 sustains). In that case, since the soft-priming light emission is below 0.1 cd/m^2 the contrast ratio is beyond 1000:1 in dark room.

However, as illustrated in Figure 5, when the number of sustain impulses grows, the biggest sub-field suffers from response fidelity problems e.g. in the case of a horizontal greyscale at the border of the PDP. In order to examine these response fidelity problems, a zoomed part of the screen is illustrated in Figure 8. A greyscale is realized by a smooth transitation from the pixel value 170 to the pixel value 176 by displaying the values alternatingly. The following sub-field code is used:

1-2-3-5-8-12-18-24-31-40-50-61.

Figure 8 shows that the response fidelity problems, in the example, are located at the cells having direct neighbours

with different values. In other words, when a cell with the value 170 has a direct neighbour (not diagonal) having the value 176, both cells have problems.

In order to learn the reasons of the problems the sub-field codewords for these values should be compared. The comparison is shown in Figure 9. Differences are given in the seventh and eighth bit.

Now, in order to learn more about the reason of the problems another zoomed part of the screen is shown in Figure 10. As apparent from this Figure there are no cells having problems. A comparison of the codewords related to Figure 10 is illustrated in Figure 11. Differences appear in the second and third bit.

The examples given above show that the problem of response fidelity appearing at a PDP border for high video level pictures are linked to the switching ON/OFF of MSB. Indeed, in the case presented Figure 8 showing artefacts, the differences between the video values 170 and 176 are located on the sub-fields 7 and 8. However, in the case presented in Figure 10 showing no artefacts, the differences are located only in the LSBs.

This problem is directly linked to the situation described above: the open cells at the PDP border. Indeed, when an open cell has a certain sub-field switched ON, it will pollute the neighbouring cells that are OFF (compare Figure 13). This is not the case for closed cells as immediately apparent from Figure 12. The cells switched ON do not influence neighbouring cells switched OFF.

The examples above show that, when a cell is open, there could be a migration of charges to the neighbouring cells. When those neighbours are ON, the migration will disappear during a discharging operation. However, when the neighbour-

ing cells are OFF, the charges will remain. The amount of charges will depend on the number of sustains used for the sub-field ON. Then, if the amount of polluting charges is strong enough, this could disturb the writing of the next sub-field for the polluted cells.

Up to a certain degree this pollution problem can be solved by applying priming operation, since the priming operation acts as reset and is able to suppress the polluting charges. In order to do that, this concept described in EP-A-1 335 341 is based on a limit Δ representing a maximal number of sustain without priming. In other words, when a sub-field contains more than Δ sustains, its priming is activated. This leads to an evolving number of priming. However, this also reduces the maximal available darkroom contrast.

In order to go further and to reduce the total amount of priming, according to the present invention it is suggested to modify the codeword at the panel border so that critical situations like that depicted in Figure 5 can no more happen.

The codewords may be modified in dependence of the average power level of a picture to be displayed. A prerequisite of this is that an adequate power management is provided.

For every kind of active display, more peak luminance corresponds also to a higher power that flows in the electronic. Therefore, if no specific management is done, the enhancement of the peak luminance for a given electronic efficacy will introduce an increase of the power consumption. The main idea behind every kind of power management concept associated with peak white enhancement is based on the variation of the peak-luminance depending on the picture content in order to stabilize the power consumption to a specified value. This is illustrated in Figure 14. The concept enables to avoid any overloading of the power-supply as well as a

maximum contrast for a given picture. In the case of analogue displays like CRTs, the power management is based on a so called ABM function (Average Beam-current Limiter), which is implemented by analogue means, and which decreases video gain as a function of average luminance, usually measured over a RC stage. In the case of a plasma display, the luminance, i.e. the picture charge, as well as the power consumption is directly linked to the number of sustains (light pulse) per frame as shown in Figure 15.

In order to avoid overloading the power supply of the plasma, the number of sustains can be adjusted depending on the picture content. When the picture is full (e.g. full white page - 100%) it is not possible to use the total amount of sustains (e.g. only 100 sustains are used) which leads to a reduced white luminance (around 100 cd/m2). This determines the power consumption (e.g. 300 W). Then when the charge of the picture decreases (e.g. night with only a small moon up to 0%), the number of sustains can be increased without increasing the power consumption. This only enhances the contrast for the human eye.

In other words, for every charge of the input picture computed through the APL (Average Power Level), a certain amount of sustain impulses will be used for the peak white as shown in Figure 15. This has the disadvantage of allowing only a reduced number of discrete power levels compared to an analogue system. The computation of the image energy (APL) is made through the following function:

$$APL(I(x,y)) = \frac{1}{C \times L} \cdot \sum_{x,y} I(x,y)$$

where I(x,y) represents the picture to be displayed, C the number of columns and L the number of lines of this picture. Then, for every possible APL values, the maximal number of sustains to be used is fixed.

Since, only an integer number of sustains can be used, there is only a limited number of available APL levels. This is illustrated in Figure 16 representing the sustain sequences for various APL levels at a given sub-fields sequence based on a 12 sub-fields Fibonacci sequence: 1-2-3-5-8-13-19-25-32-40-49-58

According to Figure 15 the number of sustains for a given sub-field is changing a lot. If one considers the case of a limit value Δ=55 of sustains under which there is no polluting problem, one can easily detect the sub-fields showing critical behaviour as shown in Figure 17. The sub-fields showing response fidelity problems are marked with grey colour. In the case of EP-A-1 335 341, these sub-fields represent the sub-fields, which would be primed. However, according to the present new concept, the codewords related to these sub-fields will be modified (depending on the APL situation). Obviously, this codeword modification will only be performed on the sub-fields showing problems at the moment where a modification is needed: there is no need to make any modification for APL=100% whereas seven sub-fields could be affected for APL=0%.

An other important aspect of the present new concept of codeword modification is its compatibility with the previous concept of dynamic priming. Indeed, both concepts can be utilized separately but a combination of both brings further improvements. On one hand, dynamic priming increases the dark level (reducing the darkroom contrast) without modifying the greyscale quality, on the other hand the concept of codeword modification limits the greyscale portrayal capability of the plasma panel in border areas while requiring no additional priming.

As already said, the inventive concept is based on a specific encoding for border areas. Figure 18 illustrates the

concept of border areas surrounding a standard area with two possibilities:

- Only one border area is used having a single limit Δ used for the codeword limitation (left side of Figure 18).

- Multiple border areas are defined, each of them having their independent limit Δ1, Δ2, Δ3 with Δ1< Δ2<Δ3 since the polluting level is reducing while moving away from the screen border (right side of Figure 18).

It is important to notice here that the border areas are really small and do not represent a main part of the screen (e.g. only 4% of the screen).

In the following the basic concept of codeword limitation shall be explained in detail. For this, the example defined in Figure 16 for the case of APL=0% and for the three limits Δ1, Δ2, Δ3 in case of multiple border areas will be utilized. The following limit values are chosen.

Δ1=55
Δ2=90
Δ3=120

In fact, the values are obtained through measurements at the panel level.

The main idea behind this concept is to forbid the insertion of 0 between two 1 for critical sub-fields. In other words, in the total amount of existing codewords, the critical ones will be suppressed. In the following table one can find the standard encoding table for the sub-field sequences used above: 1-2-3-5-8-13-19-25-32-40-49-58 as well as the suppressed codewords for all areas.

Table: Coding of three border areas

Video value	Codeword standard	Codeword for Δ_3	Codeword for Δ_2	Codeword for Δ_1
0	000000000000	000000000000	000000000000	000000000000
1	100000000000	100000000000	100000000000	100000000000
2	010000000000	010000000000	010000000000	010000000000
3	110000000000	110000000000	110000000000	110000000000
4	101000000000	101000000000	101000000000	101000000000
5	011000000000	011000000000	011000000000	011000000000
6	111000000000	111000000000	111000000000	111000000000
7	010100000000	010100000000	010100000000	010100000000
8	110100000000	110100000000	110100000000	110100000000
9	101100000000	101100000000	101100000000	101100000000
10	011100000000	011100000000	011100000000	011100000000
11	111100000000	111100000000	111100000000	111100000000
12	101010000000	101010000000	101010000000	101010000000
13	011010000000	011010000000	011010000000	011010000000
14	111010000000	111010000000	111010000000	111010000000
15	010110000000	010110000000	010110000000	010110000000
16	110110000000	110110000000	110110000000	110110000000
17	101110000000	101110000000	101110000000	101110000000
18	011110000000	011110000000	011110000000	011110000000
19	111110000000	111110000000	111110000000	111110000000
20	010101000000	010101000000	010101000000	010101000000
21	110101000000	110101000000	110101000000	110101000000
22	101101000000	101101000000	101101000000	101101000000
23	011101000000	011101000000	011101000000	011101000000
24	111101000000	111101000000	111101000000	111101000000
25	101011000000	101011000000	101011000000	101011000000
26	011011000000	011011000000	011011000000	011011000000
27	111011000000	111011000000	111011000000	111011000000
28	010111000000	010111000000	010111000000	010111000000
29	110111000000	110111000000	110111000000	110111000000
30	101111000000	101111000000	101111000000	101111000000
31	011111000000	011111000000	011111000000	011111000000
32	111111000000	111111000000	111111000000	111111000000
33	111010100000	111010100000	111010100000	XXXXXXXXXXXX
34	010110100000	010110100000	010110100000	XXXXXXXXXXXX
35	110110100000	110110100000	110110100000	XXXXXXXXXXXX
36	101110100000	101110100000	101110100000	XXXXXXXXXXXX
37	011110100000	011110100000	011110100000	XXXXXXXXXXXX
38	111110100000	111110100000	111110100000	XXXXXXXXXXXX
39	010101100000	010101100000	010101100000	010101100000
40	110101100000	110101100000	110101100000	110101100000
41	101101100000	101101100000	101101100000	101101100000
42	011101100000	011101100000	011101100000	011101100000
43	111101100000	111101100000	111101100000	111101100000
44	101011100000	101011100000	101011100000	101011100000
45	011011100000	011011100000	011011100000	011011100000
46	111011100000	111011100000	111011100000	111011100000
47	010111100000	010111100000	010111100000	010111100000
48	110111100000	110111100000	110111100000	110111100000
49	101111100000	101111100000	101111100000	101111100000
50	011111100000	011111100000	011111100000	011111100000
51	111111100000	111111100000	111111100000	111111100000
52	111011010000	111011010000	XXXXXXXXXXXX	XXXXXXXXXXXX

53	010111010000	010111010000	XXXXXXXXXXXX	XXXXXXXXXXXX
54	110111010000	110111010000	XXXXXXXXXXXX	XXXXXXXXXXXX
55	101111010000	101111010000	XXXXXXXXXXXX	XXXXXXXXXXXX
56	011111010000	011111010000	XXXXXXXXXXXX	XXXXXXXXXXXX
57	111111010000	111111010000	XXXXXXXXXXXX	XXXXXXXXXXXX
58	111010110000	111010110000	111010110000	XXXXXXXXXXXX
59	010110110000	010110110000	010110110000	XXXXXXXXXXXX
60	110110110000	110110110000	110110110000	XXXXXXXXXXXX
61	101110110000	101110110000	101110110000	XXXXXXXXXXXX
62	011110110000	011110110000	011110110000	XXXXXXXXXXXX
63	111110110000	111110110000	111110110000	XXXXXXXXXXXX
64	010101110000	010101110000	010101110000	010101110000
65	110101110000	110101110000	110101110000	110101110000
66	101101110000	101101110000	101101110000	101101110000
67	011101110000	011101110000	011101110000	011101110000
68	111101110000	111101110000	111101110000	111101110000
69	101011110000	101011110000	101011110000	101011110000
70	011011110000	011011110000	011011110000	011011110000
71	111011110000	111011110000	111011110000	111011110000
72	010111110000	010111110000	010111110000	010111110000
73	110111110000	110111110000	110111110000	110111110000
74	101111110000	101111110000	101111110000	101111110000
75	011111110000	011111110000	011111110000	011111110000
76	111111110000	111111110000	111111110000	111111110000
77	011011101000	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
78	111011101000	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
79	010111101000	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
80	110111101000	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
81	101111101000	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
82	011111101000	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
83	111111101000	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
84	111011011000	111011011000	XXXXXXXXXXXX	XXXXXXXXXXXX
85	010111011000	010111011000	XXXXXXXXXXXX	XXXXXXXXXXXX
86	110111011000	110111011000	XXXXXXXXXXXX	XXXXXXXXXXXX
87	101111011000	101111011000	XXXXXXXXXXXX	XXXXXXXXXXXX
88	011111011000	011111011000	XXXXXXXXXXXX	XXXXXXXXXXXX
89	111111011000	111111011000	XXXXXXXXXXXX	XXXXXXXXXXXX
90	111010111000	111010111000	111010111000	XXXXXXXXXXXX
91	010110111000	010110111000	010110111000	XXXXXXXXXXXX
92	110110111000	110110111000	110110111000	XXXXXXXXXXXX
93	101110111000	101110111000	101110111000	XXXXXXXXXXXX
94	011110111000	011110111000	011110111000	XXXXXXXXXXXX
95	111110111000	111110111000	111110111000	XXXXXXXXXXXX
96	010101111000	010101111000	010101111000	010101111000
97	110101111000	110101111000	110101111000	110101111000
98	101101111000	101101111000	101101111000	101101111000
99	011101111000	011101111000	011101111000	011101111000
100	111101111000	111101111000	111101111000	111101111000
101	101011111000	101011111000	101011111000	101011111000
102	011011111000	011011111000	011011111000	011011111000
103	111011111000	111011111000	111011111000	111011111000
104	010111111000	010111111000	010111111000	010111111000
105	110111111000	110111111000	110111111000	110111111000
106	101111111000	101111111000	101111111000	101111111000
107	011111111000	011111111000	011111111000	011111111000
108	111111111000	111111111000	111111111000	111111111000
109	101011110100	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
110	011011110100	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX

111	111011110100	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
112	010111110100	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
113	110111110100	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
114	101111110100	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
115	011111110100	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
116	111111110100	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
117	011011101100	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
118	111011101100	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
119	010111101100	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
120	110111101100	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
121	101111101100	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
122	011111101100	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
123	111111101100	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
124	111011011100	111011011100	XXXXXXXXXXXX	XXXXXXXXXXXX
125	010111011100	010111011100	XXXXXXXXXXXX	XXXXXXXXXXXX
126	110111011100	110111011100	XXXXXXXXXXXX	XXXXXXXXXXXX
127	101111011100	101111011100	XXXXXXXXXXXX	XXXXXXXXXXXX
128	011111011100	011111011100	XXXXXXXXXXXX	XXXXXXXXXXXX
129	111111011100	111111011100	XXXXXXXXXXXX	XXXXXXXXXXXX
130	111010111100	111010111100	111010111100	XXXXXXXXXXXX
131	010110111100	010110111100	010110111100	XXXXXXXXXXXX
132	110110111100	110110111100	110110111100	XXXXXXXXXXXX
133	101110111100	101110111100	101110111100	XXXXXXXXXXXX
134	011110111100	011110111100	011110111100	XXXXXXXXXXXX
135	111110111100	111110111100	111110111100	XXXXXXXXXXXX
136	010101111100	010101111100	010101111100	010101111100
137	110101111100	110101111100	110101111100	110101111100
138	101101111100	101101111100	101101111100	101101111100
139	011101111100	011101111100	011101111100	011101111100
140	111101111100	111101111100	111101111100	111101111100
141	101011111100	101011111100	101011111100	101011111100
142	011011111100	011011111100	011011111100	011011111100
143	111011111100	111011111100	111011111100	111011111100
144	010111111100	010111111100	010111111100	010111111100
145	110111111100	110111111100	110111111100	110111111100
146	101111111100	101111111100	101111111100	101111111100
147	011111111100	011111111100	011111111100	011111111100
148	111111111100	111111111100	111111111100	111111111100
149	111101111010	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
150	101011111010	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
151	011011111010	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
152	111011111010	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
153	010111111010	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
154	110111111010	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
155	101111111010	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
156	011111111010	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
157	111111111010	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
158	101011110110	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
159	011011110110	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
160	111011110110	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
161	010111110110	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
162	110111110110	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
163	101111110110	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
164	011111110110	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
165	111111110110	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
166	011011101110	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
167	111011101110	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
168	010111101110	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX

169	110111101110	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
170	101111101110	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
171	011111101110	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
172	111111101110	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
173	111011011110	111011011110	XXXXXXXXXXX	XXXXXXXXXXX
174	010111011110	010111011110	XXXXXXXXXXX	XXXXXXXXXXX
175	110111011110	110111011110	XXXXXXXXXXX	XXXXXXXXXXX
176	101111011110	101111011110	XXXXXXXXXXX	XXXXXXXXXXX
177	011111011110	011111011110	XXXXXXXXXXX	XXXXXXXXXXX
178	111111011110	111111011110	XXXXXXXXXXX	XXXXXXXXXXX
179	111010111110	111010111110	111010111110	XXXXXXXXXXX
180	010110111110	010110111110	010110111110	XXXXXXXXXXX
181	110110111110	110110111110	110110111110	XXXXXXXXXXX
182	101110111110	101110111110	101110111110	XXXXXXXXXXX
183	011110111110	011110111110	011110111110	XXXXXXXXXXX
184	111110111110	111110111110	111110111110	XXXXXXXXXXX
185	010101111110	010101111110	010101111110	010101111110
186	110101111110	110101111110	110101111110	110101111110
187	101101111110	101101111110	101101111110	101101111110
188	011101111110	011101111110	011101111110	011101111110
189	111101111110	111101111110	111101111110	111101111110
190	101011111110	101011111110	101011111110	101011111110
191	011011111110	011011111110	011011111110	011011111110
192	111011111110	111011111110	111011111110	111011111110
193	010111111110	010111111110	010111111110	010111111110
194	110111111110	110111111110	110111111110	110111111110
195	101111111110	101111111110	101111111110	101111111110
196	011111111110	011111111110	011111111110	011111111110
197	111111111110	111111111110	111111111110	111111111110
198	111101111101	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
199	101011111101	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
200	011011111101	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
201	111011111101	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
202	010111111101	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
203	110111111101	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
204	101111111101	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
205	011111111101	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
206	111111111101	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
207	111101111011	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
208	101011111011	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
209	011011111011	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
210	111011111011	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
211	010111111011	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
212	110111111011	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
213	101111111011	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
214	011111111011	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
215	111111111011	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
216	101011110111	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
217	011011110111	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
218	111011110111	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
219	010111110111	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
220	110111110111	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
221	101111110111	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
222	011111110111	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
223	111111110111	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
224	011011101111	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
225	111011101111	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX
226	010111101111	XXXXXXXXXXX	XXXXXXXXXXX	XXXXXXXXXXX

227	110111101111	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
228	101111101111	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
229	011111101111	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
230	111111101111	XXXXXXXXXXXX	XXXXXXXXXXXX	XXXXXXXXXXXX
231	111011011111	111011011111	XXXXXXXXXXXX	XXXXXXXXXXXX
232	010111011111	010111011111	XXXXXXXXXXXX	XXXXXXXXXXXX
233	110111011111	110111011111	XXXXXXXXXXXX	XXXXXXXXXXXX
234	101111011111	101111011111	XXXXXXXXXXXX	XXXXXXXXXXXX
235	011111011111	011111011111	XXXXXXXXXXXX	XXXXXXXXXXXX
236	111111011111	111111011111	XXXXXXXXXXXX	XXXXXXXXXXXX
237	111010111111	111010111111	111010111111	XXXXXXXXXXXX
238	010110111111	010110111111	010110111111	XXXXXXXXXXXX
239	110110111111	110110111111	110110111111	XXXXXXXXXXXX
240	101110111111	101110111111	101110111111	XXXXXXXXXXXX
241	011110111111	011110111111	011110111111	XXXXXXXXXXXX
242	111110111111	111110111111	111110111111	XXXXXXXXXXXX
243	010101111111	010101111111	010101111111	010101111111
244	110101111111	110101111111	110101111111	110101111111
245	101101111111	101101111111	101101111111	101101111111
246	011101111111	011101111111	011101111111	011101111111
247	111101111111	111101111111	111101111111	111101111111
248	101011111111	101011111111	101011111111	101011111111
249	011011111111	011011111111	011011111111	011011111111
250	111011111111	111011111111	111011111111	111011111111
251	010111111111	010111111111	010111111111	010111111111
252	110111111111	110111111111	110111111111	110111111111
253	101111111111	101111111111	101111111111	101111111111
254	011111111111	011111111111	011111111111	011111111111

In the example shown in the table, the first column corresponds to the video value to be rendered, the second column to the standard codeword (used in the standard area of the panel as described on Figure 18, the third, fourth and fifth respectively to the codeword used in the areas Δ1, Δ2, Δ3. In these three last columns, codeword xxxxxxxxxxxx means dropped codeword (not used).

For instance, in the area Δ1, the video values 33 up to 38 are not rendered whereas they are rendered in the two other areas.

Indeed, the video level 33 is rendered with the codeword 111010100000 in the standard area. In case of APL=0%, the 6th sub-field has an energy of 71 sustains which is more than Δ1 but lower than Δ2 and Δ3. In this codeword, the 6th sub-field is set to zero whereas the 7th is set to one,

which represents a critical situation as described in Figure 9. Therefore, the codeword is dropped for area Δ1 only.

Later on, the missing levels will be recreated by the means of dithering. Even if this concept will increase a bit the dithering noise in the border areas, it has to be remembered that those areas are very small (e.g. 4% of screen size) and do not represent the main area for the human eye. In that case the limitations introduced by the specific border coding will not be really noticeable for the viewer but the gain in terms of contrast (less priming used) will be quite strong. Indeed, in the example at APL=0%, one signal priming instead of 8 is enough, so that the contrast has been improved by a factor 8.

Following number of levels are suppressed in the example:

Δ1:145 codewords are suppressed
Δ2:109 codewords are suppressed
Δ3: 79 codewords are suppressed

Moreover, fewer levels will be suppressed in the case of a combination with dynamic priming. In that case, a trade-off should be chosen between the number of sub-fields used for dropping and the number of additional priming. The ideal position for the primed sub-fields will be on the lowest sub-fields from the critical group (all sub-fields having more than Δn sustains) since the number of codewords to be dropped will be more reduced in that case.

Furthermore, the suppression is done only for law APL values as seen on Figure 17.

A hardware implementation of the border-coding concept for a PDP panel is shown in Figure 19. Input 8-bit R, G, B is forwarded to the video-degamma function block 1 (mathematical function or LUT), which outputs the signal with more resolu-

tion (at least 10 bits). This signal is forwarded both to a power measurement block 2 and to the video-mapping block 3. The power measurement block 2 measures the Average Power level APL of the video signal.

Depending on the Average Power Level (APL), the control system 4 determines the sustain table and the encoding table with its sub-fields number. Furthermore, this basic information APL is sent to a border select block 5 so that a correct decision regarding the critical areas can be taken. To do that, the border select block also disposes of position information (H-line and Clock-pixel) so that the right Δ area can be determined. Additionally, the border select block 5 receives a control signal BORD from the system control block 4. This control signal BORD is used for activating the specific border coding. The Δ information output from the border select block 5 as well as a mapping information (related to the encoding and sustain table) is sent to the video mapping block 3 which modifies the video data so that the dropped video parts can be recreated correctly with the dithering function.

After the mapping stage in video mapping block 3, data are forwarded to a dithering block 6 replacing non-encodable video levels. Then, the encoding to codewords of a 10 bit RGB signal from the dithering block 6 is performed by the sub-field coding block 7 receiving coding information from the system control block 4 concerning the decision which LUT should be used for sub-field coding.

The system control block 4 also controls the writing of 16 bit RGB pixel data from the sub-field coding block 7 in a 2-frame memory 8 (WR), the reading (RD) of RGB sub-field data from a second frame memory integrated in the 2-frame memory 8, and the serial to parallel conversion circuit (SP) in a serial-parallel conversion block 9 receiving the output signals SF-R, SF-G,SF-B from the 2-frame memory 8.

The 2-frame memory 8 is required, since data is written pixel-wise, but read sub-field-wise. In order to read the complete first sub-field a whole frame must already be present in the memory 8. In a practical implementation two whole frame memories are present, and while one frame memory is being written, the other is being read, avoiding in this way reading the wrong data. In a cost optimized architecture, the two frame memories are located on the same SDRAM memory IC, and the access to the two frames is time multiplexed.

The serial-parallel conversion block 9 outputs top and bottom data for the plasma display panel 10. Finally the system control block 4 including an addressing and sustain control unit 42 generates the SCAN and SUSTAIN pulses required to drive the PDP driver circuits of the PDP 10.

In summary in this document, it was shown how the use of a new coding concept can optimize the picture quality regarding the contrast as well as the response fidelity. Subjective tests performed in dark room environment have shown good picture quality assessment regarding classical PDPs.